HAYNES

An Investigation of the
Water Pressure Ejector

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# AN INVESTIGATION OF THE WATER PRESSURE EJECTOR

BY

MARK ROSS HAYNES

THESIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

MARK ROSS HAYNES

ENTITLED AN INVESTIGATION OF THE WATER PRESSURE EJECTOR

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

A N Talbot

T. R. Agg.

Instructor in Charge.

APPROVED: Ira O Baker

HEAD OF DEPARTMENT OF Civil Engineering

# Theory

The theory of the jet pump has long been known and was used as early as 1850. The invention of this style of pump is credited to James Thompson C.E., who claimed that it could be used to pump out pits for submerged water wheels, and also in draining out marshes where there were abundant waterfalls. This style of pump or something very similar, called a rush of water was actually used in draining out some of the low-lands of Italy, but no definite account of its action can be found. Although the jet pump has been used to some extent, yet practically nothing is known of its range of operation or efficiency. The object of this investigation is to determine the range of operation and efficiency of two jet pumps. (1) One was made of

standard pipe fittings and constructed in the laboratory. (2) The other was an ordinary Chicago ejector and a slight modification of it.

These investigations were suggested by the idea that perhaps the jet pump could be used with satisfaction where there was plenty of water to be had at a fairly high pressure, a high efficiency not being necessary. These conditions would be found in the cities which owned their own water system and did their own sewer work.

## Description of Apparatus

The apparatus was set up as shown in Plate I. The horizontal pipe A contains the water which is under pressure, this pressure being measured by the water gauge E. B is the suction pipe the bottom end of which is

always below the level of the water in the pit. D is a double elbow in the pipe so that the distance H may be made greater or smaller by inclining at a greater or less angle the discharge end C. The tank used to weigh the water is shown on the scales. These scales are standardized to be used in the department, so that their weights may be accepted as correct. G is the feeder pipe which supplies water to the pit as fast as it is pumped out through the suction pipe B. The hook-gauge shown was used to make it easier to keep the level of the water at the same position during the run, and especially at the beginning and the end. The water meter at I was used to measure the quantity of water flowing through the feeder pipe during the run, this quantity also being equal to the amount pumped. This meter was calibrated before the experiments were started and

the calibration constant and tables are given in Table I. The valve K was used to regulate the flow in the feeder pipe so that the water could be allowed to flow in as fast as it was pumped out. The pit shown was about $6 \times 14 \times 5\frac{1}{2}$ feet deep. This depth limited the range of suction to five feet.

## Method of Testing.

The water in the pit was first brought to the desired level and the hook gauge was then raised or lowered until it just lifted the skin of the water in which position it was then clamped. The distance S or the suction distance was then measured and recorded. The inclined pipe C was placed at a certain angle and the distance H was measured and recorded. A reading was taken of the weight of the tank as indicated by the

scales and also a reading of the water meter and the run was ready to start.

At an initial time the valve at A was opened until the gauge I gave a certain head pressure which was recorded. The valve K in the feeder pipe G was now opened enough to keep the water level in the pit as constant as possible. A small variation of the level of the water in the pit did not make an appreciable difference in the results, providing that the levels at the beginning and end of the run were the same. The method employed was to keep the level of the water a fraction lower than the level at the start of the run, as this made it possible to stop the run at any time without the chance of having too much water in the pit. If on the other hand there was not enough water in the pit when the final readings were taken the

water was allowed to run in the pipe G until the level was at the correct height. The experiment was allowed to run 8 or 10 minutes in which time the tank which holds about 32 cubic feet net capacity was about full, and then the shut-off valve A was closed and the time recorded. If the water in the pit was at the correct level as shown by the hook gauge, the valve K was also closed. If this was not the case the valve K was left open until the hook gauge showed the water to be at the correct level. Final readings were now taken of the water meter I, and the weight of the tank, and the experiment was finished.

## Observations.

In order to obtain the efficiencies of all combinations of suction heads (S), pressure heads

(E) and lift heads H, the following method was employed. The suction head S was made as great as possible. The maximum value of S was about 5 feet as this was the difference which could be made in the levels of the water in the pit. The distance H was made as small as possible. The range of the distance H was from about 2 feet to 6 feet, that is, the end of pipe C could be raised or lowered through this distance without either striking the ceiling in one direction or the tank in the other.

Three reading were now taken using three different pressure heads. One as high as could be obtained, one at about the minimum that water could be pumped and the other midway between. The pressure heads used ranged from twenty to ninety feet. The next three readings were obtained in

this manner. The suction head S was still kept the same but the distance H was increased about a foot. The three readings were taken by using the three different pressure heads as before. This method was kept up until the distance H was made as great as possible. The readings obtained so far will be called a set. In order to obtain Set II the suction distance S was decreased about two feet and the second set was taken as above described. In this manner all possible combinations that could be made were obtained.

Methods of calculating results and formulae used.

(1) Quantity pumped.

The quantity of water pumped was found in cubic feet per second by subtracting the final and initial

readings of the meter I, and dividing the result by the duration of time in seconds.

(2) Quantity used.

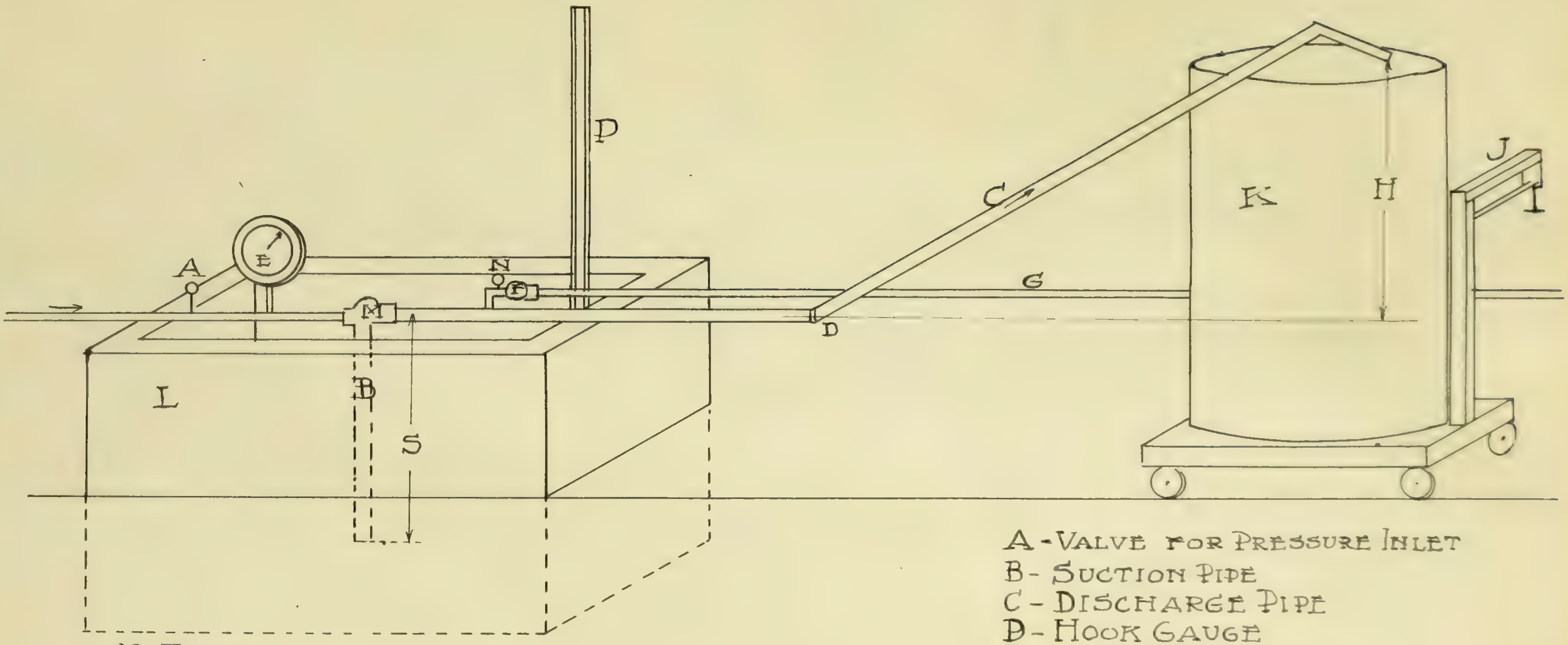
The total quantity flowing through the pipe C in pounds was found by subtracting the initial from the final reading of the scales. This was reduced to cubic feet per second by dividing the difference by 62.5 times the duration of run in seconds. The quantity used in cubic feet per second would be the number just found minus the number found under the quantity pumped.

Efficiency

Let $W_1$ = weight of water pumped
" $W_2$ = " " " used
" $S$ = Value of suction head in feet
" $H$ = Distance as shown in figure
" $P$ = Pressure head as given by gauge
" $E$ = Efficiency

$$E = \frac{W_1(S+H) + W_2 H}{(W_1 + W_2)P}$$

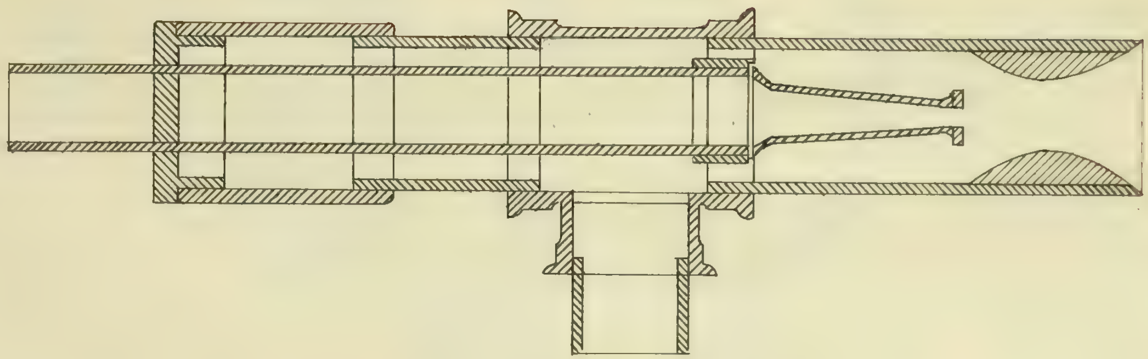
# Plate 1




K - Tank
L - Pit
M - Ejector
N - Valve for Feeder Pipe

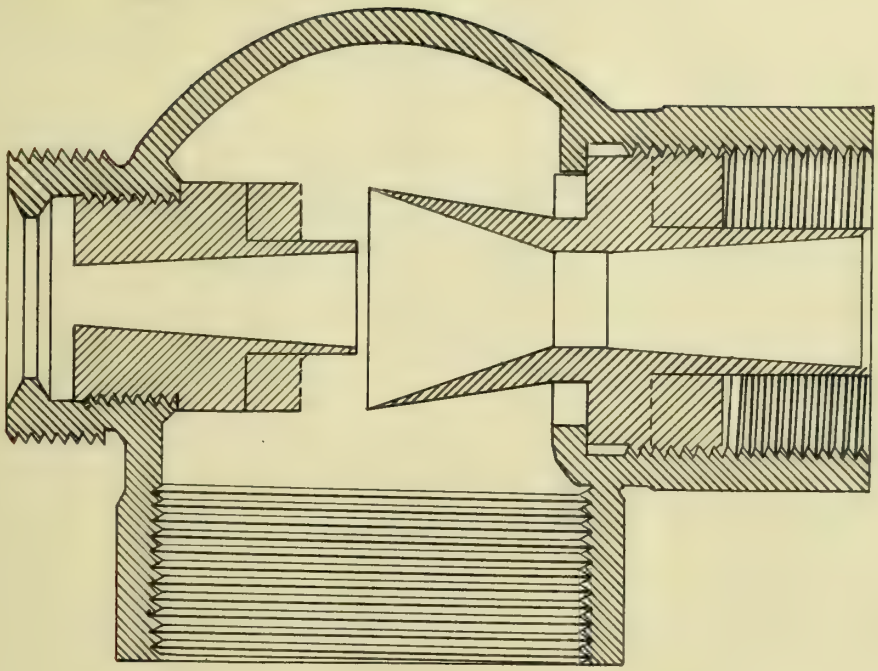
A - Valve for Pressure Inlet
B - Suction Pipe
C - Discharge Pipe
D - Hook Gauge
E - Pressure Gauge
D - Double Elbow
F - Herseys Water Meter
G - Feeder Pipe
H - Lift Head
J - Scales

PLATE 2.

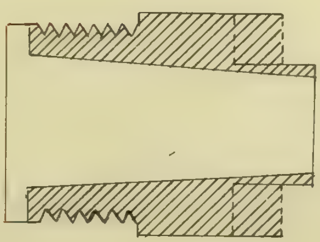


JET PUMP

# PLATE 3



CHICAGO EJECTOR



MODIFIED NIPPLE

# TABLE A.

## TEST OF A ONE INCH CHICAGO EJECTOR.

| No | PRESSURE HEAD IN FEET | SUCTION HEAD IN FEET | TOTAL HEAD IN FEET | WATER PUMPED IN CUBIC FEET | WATER USED IN CUBIC FEET | EFFICIENCY IN PER CENT | GAL. PUMPED PER GAL. USED |
|---|---|---|---|---|---|---|---|
| 1 | 90 | 5.0 | 6.8 | 0.0317 | 0.0407 | 7.90 | 0.778 |
| 2 | 70 | 5.0 | 6.8 | 0.0226 | 0.0351 | 8.83 | 0.645 |
| 3 | 50 | 5.0 | 6.8 | 0.0081 | 0.0336 | 6.88 | 0.231 |
| 4 | 90 | 5.0 | 7.8 | 0.0271 | 0.0429 | 8.30 | 0.632 |
| 5 | 70 | 5.0 | 7.8 | 0.0179 | 0.0371 | 9.46 | 0.482 |
| 6 | 50 | 5.0 | 7.8 | 0.0050 | 0.0340 | 7.90 | 0.147 |
| 7 | 90 | 5.0 | 8.8 | 0.0276 | 0.0413 | 10.76 | 0.669 |
| 8 | 70 | 5.0 | 8.8 | 0.0185 | 0.0366 | 11.79 | 0.550 |
| 9 | 50 | 5.0 | 8.8 | 0.0016 | 0.0348 | 8.42 | 0.046 |
| 10 | 90 | 3.0 | 6.8 | 0.0254 | 0.0507 | 8.04 | 0.502 |
| 11 | 70 | 3.0 | 6.8 | 0.0194 | 0.0363 | 10.62 | 0.577 |
| 12 | 50 | 3.0 | 6.8 | 0.0080 | 0.0313 | 11.10 | 0.255 |
| 13 | 80 | 3.0 | 5.8 | 0.0264 | 0.0396 | 8.42 | 0.668 |
| 14 | 70 | 3.0 | 5.8 | 0.0219 | 0.0371 | 8.84 | 0.590 |
| 15 | 50 | 3.0 | 5.8 | 0.0103 | 0.0325 | 9.35 | 0.262 |
| 16 | 80 | 3.0 | 5.1 | 0.0264 | 0.0417 | 6.63 | 0.633 |
| 17 | 60 | 3.0 | 5.1 | 0.0262 | 0.0360 | 7.52 | 0.728 |
| 18 | 40 | 3.0 | 5.1 | 0.0170 | 0.0258 | 7.53 | 0.660 |
| 19 | 60 | 0.3 | 2.3 | 0.0226 | 0.0364 | 5.68 | 0.621 |

# TABLE A CONTINUED

## TEST OF A ONE INCH CHICAGO EJECTOR

| No | PRESSURE HEAD IN FEET | SUCTION HEAD IN FEET | TOTAL HEAD IN FEET | WATER PUMPED IN CUBIC FEET | WATER USED IN CUBIC FEET | EFFICIENCY IN PER CENT | GAL. PUMPED PER GAL. USED |
|---|---|---|---|---|---|---|---|
| 20 | 40 | 03 | 2.3 | 0.0129 | 0.0309 | 7.40 | 0.417 |
| 21 | 30 | 0.3 | 2.3 | 0.0072 | 0.0291 | 8.58 | 0.248 |
| 22 | 60 | 0.3 | 3.3 | 0.0201 | 0.0350 | 8.17 | 0.575 |
| 23 | 45 | 0.3 | 3.3 | 0.0112 | 0.0322 | 9.22 | 0.348 |
| 24 | 30 | 0.3 | 3.3 | 0.0032 | 0.029.5 | 11.20 | 0.108 |
| 25 | 70 | 0.3 | 4.3 | 0.0240 | 0.0365 | 9.77 | 0.657 |
| 26 | 50 | 0.3 | 4.3 | 0.0104 | 0.0342 | 9.70 | 0.304 |
| 27 | 60 | 4.9 | 11.0 | 0.0027 | 0.0355 | 10.70 | 0.076 |
| 28 | 60 | 49 | 9.6 | 0.0061 | 0.0416 | 10.18 | 0.146 |
| 29 | 50 | 0.4 | 6.6 | 0.0058 | 0.0378 | 14.40 | 0.153 |
| 30 | 55 | 0.4 | 5.1 | 0.0121 | 0.0439 | 11.10 | 0.276 |

# TABLE B.

## TEST OF A MODIFIED CHICAGO EJECTOR

| No | Pressure Head in feet | Suction Head in feet | Total Head in feet | Water Pumped in cubic feet | Water Used in cubic feet | Efficiency in per cent | Gal. Pumped per Gal. Used |
|---|---|---|---|---|---|---|---|
| 1 | 60 | 3.0 | 6.8 | 0.0385 | 0.0575 | 13.9 | 0.670 |
| 2 | 50 | 3.0 | 6.8 | 0.0327 | 0.0538 | 15.4 | 0.608 |
| 3 | 40 | 3.0 | 6.8 | 0.0248 | 0.0492 | 18.1 | 0.504 |
| 4 | 30 | 3.0 | 6.8 | 0.0224 | 0.0384 | 26.6 | 0.584 |
| 5 | 50 | 3.0 | 5.8 | 0.0341 | 0.0528 | 13.0 | 0.645 |
| 6 | 35 | 3.0 | 5.8 | 0.0254 | 0.0441 | 17.5 | 0.575 |
| 7 | 20 | 3.0 | 5.8 | 0.0136 | 0.0341 | 27.9 | 0.399 |
| 8 | 50 | 3.0 | 4.8 | 0.0349 | 0.0535 | 10.0 | 0.652 |
| 9 | 35 | 3.0 | 4.8 | 0.0278 | 0.0436 | 12.8 | 0.638 |
| 10 | 20 | 3.0 | 4.8 | 0.0210 | 0.0300 | 25.8 | 0.700 |
| 11 | 60 | 0.5 | 2.3 | 0.0490 | 0.0515 | 6.9 | 0.952 |
| 12 | 40 | 0.5 | 2.3 | 0.0358 | 0.0416 | 9.9 | 0.860 |
| 13 | 20 | 0.5 | 2.3 | 0.0193 | 0.0337 | 15.6 | 0.573 |
| 14 | 60 | 0.5 | 3.3 | 0.0428 | 0.0546 | 9.0 | 0.785 |
| 15 | 40 | 0.5 | 3.3 | 0.0316 | 0.0456 | 12.7 | 0.693 |
| 16 | 20 | 0.5 | 3.3 | 0.0175 | 0.0337 | 20.2 | 0.520 |
| 17 | 40 | 0.5 | 4.3 | 0.0271 | 0.0394 | 17.9 | 0.688 |
| 18 | 20 | 0.5 | 4.3 | 0.0149 | 0.0332 | 28.6 | 0.449 |

# TABLE C.

## TEST OF JET PUMP MADE OF PIPE FITTINGS.

| No. | Pressure Head in feet | Suction Head in feet | Total Head in feet | Water Pumped in cubic feet | Water Used in cubic feet | Efficiency in per cent | Gal. Pumped per Gal. Used |
|---|---|---|---|---|---|---|---|
| 1 | 60 | 2.00 | 5.29 | 0.0156 | 0.0360 | 9.30 | 0.434 |
| 2 | 46 | 2.00 | 5.29 | 0.0058 | 0.0234 | 10.78 | 0.214 |
| 3 | 45 | 4.00 | 5.80 | 0.0067 | 0.0424 | 6.03 | 0.158 |
| 4 | 35 | 1.80 | 3.40 | 0.0058 | 0.0297 | 5.50 | 0.195 |
| 5 | 35 | 1.80 | 3.40 | 0.0066 | 0.0285 | 6.70 | 0.221 |

# TABLE D.

## CHICAGO EJECTOR

| Pressure Head | Gal. Pumped per Gal. Used | | | | | |
|---|---|---|---|---|---|---|
| | Total Head | | Total Head | | Total Head | |
| | Lift | Suction | Lift | Suction | Lift | Suction |
| | 1.8 | 5.0 | 2.8 | 5.0 | 3.8 | 5.0 |
| 90 | 0.778 | | 0.632 | | 0.669 | |
| 70 | 0.645 | | 0.482 | | 0.550 | |
| 50 | 0.231 | | 0.147 | | 0.046 | |
| | Total Head | | Total Head | | Total Head | |
| | Lift | Suction | Lift | Suction | Lift | Suction |
| | 3.8 | 3.0 | 2.8 | 3.0 | 2.1 | 3.0 |
| 90 | 0.502 | | | | | |
| 80 | | | 0.668 | | 0.633 | |
| 70 | 0.577 | | 0.590 | | | |
| 60 | | | | | 0.728 | |
| 50 | 0.255 | | 0.262 | | | |
| 40 | | | | | 0.660 | |
| | Total Head | | Total Head | | Total Head | |
| | Lift | Suction | Lift | Suction | Lift | Suction |
| | 2.0 | 0.3 | 3.0 | 0.3 | 4.0 | 0.3 |
| 70 | | | | | 0.657 | |
| 60 | 0.625 | | 0.575 | | | |
| 50 | | | | | 0.304 | |
| 45 | | | 0.348 | | | |
| 40 | 0.417 | | | | | |
| 30 | 0.248 | | 0.108 | | | |
| | Total Head | | Total Head | | Total Head | |
| | Lift | Suction | Lift | Suction | Lift | Suction |
| | 6.1 | 4.9 | 4.7 | 4.9 | | |
| 60 | 0.076 | | 0.146 | | | |
| | Total Head | | Total Head | | Total Head | |
| | Lift | Suction | | | | |
| | 6.6 | 0.4 | | | | |
| 50 | 0.153 | | | | | |

# TABLE E.

## MODIFIED CHICAGO EJECTOR

| PRESSURE HEAD | GAL. PUMPED PER GAL. USED | | | | | |
|---|---|---|---|---|---|---|
| | TOTAL HEAD | | TOTAL HEAD | | TOTAL HEAD | |
| | LIFT | SUCTION | LIFT | SUCTION | LIFT | SUCTION |
| | 3.8 | 3.0 | 2.8 | 3.0 | 1.8 | 3.0 |
| 60 | 0.670 | | | | | |
| 50 | 0.608 | | 0.645 | | 0.652 | |
| 40 | 0.504 | | | | | |
| 35 | | | 0.575 | | 0.638 | |
| 30 | 0.584 | | | | | |
| 20 | | | 0.399 | | 0.700 | |
| | TOTAL HEAD | | TOTAL HEAD | | TOTAL HEAD | |
| | LIFT | SUCTION | LIFT | SUCTION | LIFT | SUCTION |
| | 1.8 | 0.5 | 2.8 | 0.5 | 3.8 | 0.5 |
| 60 | 0.952 | | 0.785 | | | |
| 40 | 0.860 | | 0.693 | | 0.688 | |
| 20 | 0.573 | | 0.520 | | 0.449 | |

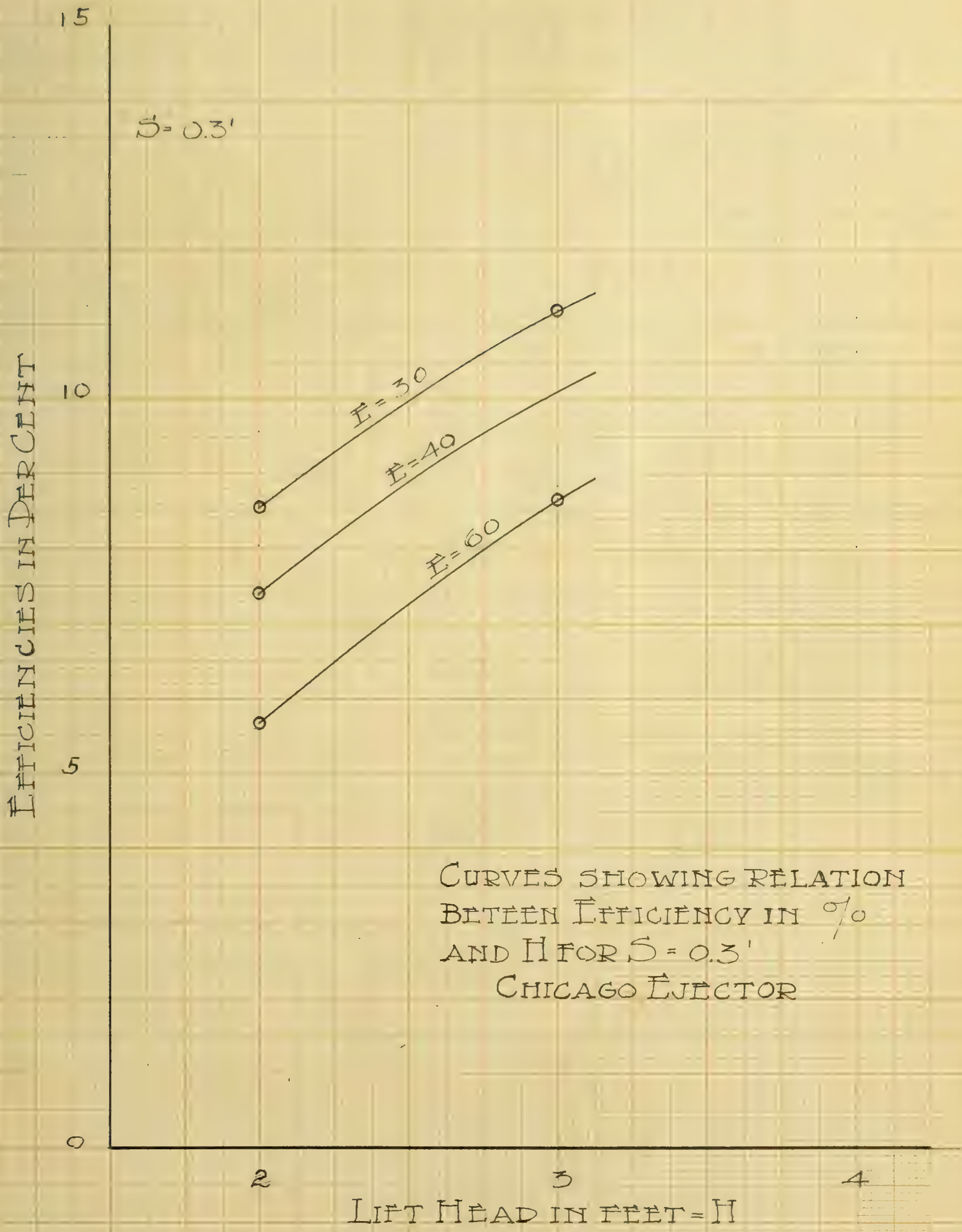
# TABLE F

## CALIBRATION OF A HERSEYS METER

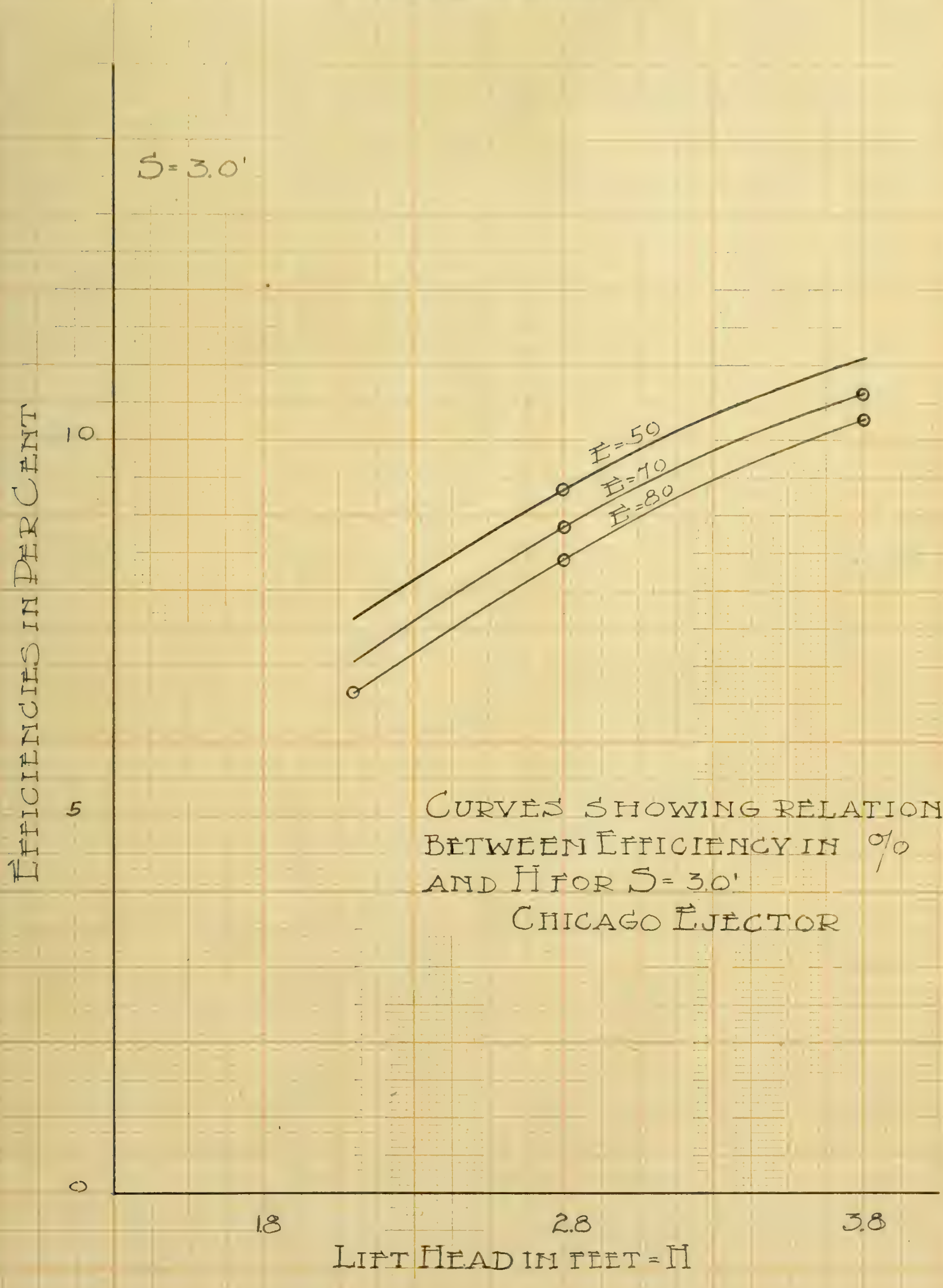
| INITIAL WEIGHT $W_1$ | FINAL WEIGHT $W_2$ | $W_2 - W_1$ IN POUNDS | INITIAL METER $R_1$ | FINAL METER $R_2$ | $R_2 - R_1$ IN CUBIC FEET | $W_2 - W_1$ IN CUBIC FEET |
|---|---|---|---|---|---|---|
| 913 | 1129 | 316 | 1219.50 | 1224.70 | 5.20 | 5.06 |
| 1229 | 1512 | 283 | | 1229.25 | 4.55 | 4.53 |
| 1512 | 1828 | 316 | | 1234.40 | 5.15 | 5.06 |
| 485 | 765 | 280 | | 1239.02 | 4.62 | 4.48 |
| 765 | 1105 | 340 | | 1244.10 | 5.58 | 5.44 |
| 1105 | 1422 | 317 | | 1249.80 | 5.20 | 5.07 |
| 1422 | 1739 | 317 | | 1255.00 | 5.20 | 5.07 |
| 470 | 1016 | 546 | | 1264.00 | 9.00 | 8.74 |
| 937 | 1553 | 616 | | 1284.00 | 10.00 | 9.87 |
| 446 | 1612 | 1166 | 1274.00 | 1303.00 | 19.00 | 18.55 |
| | | | | TOTAL | 73.50 | 71.81 |

$$\frac{71.81}{73.50} = .978 \text{ CALIBRATION CONSTANT}$$

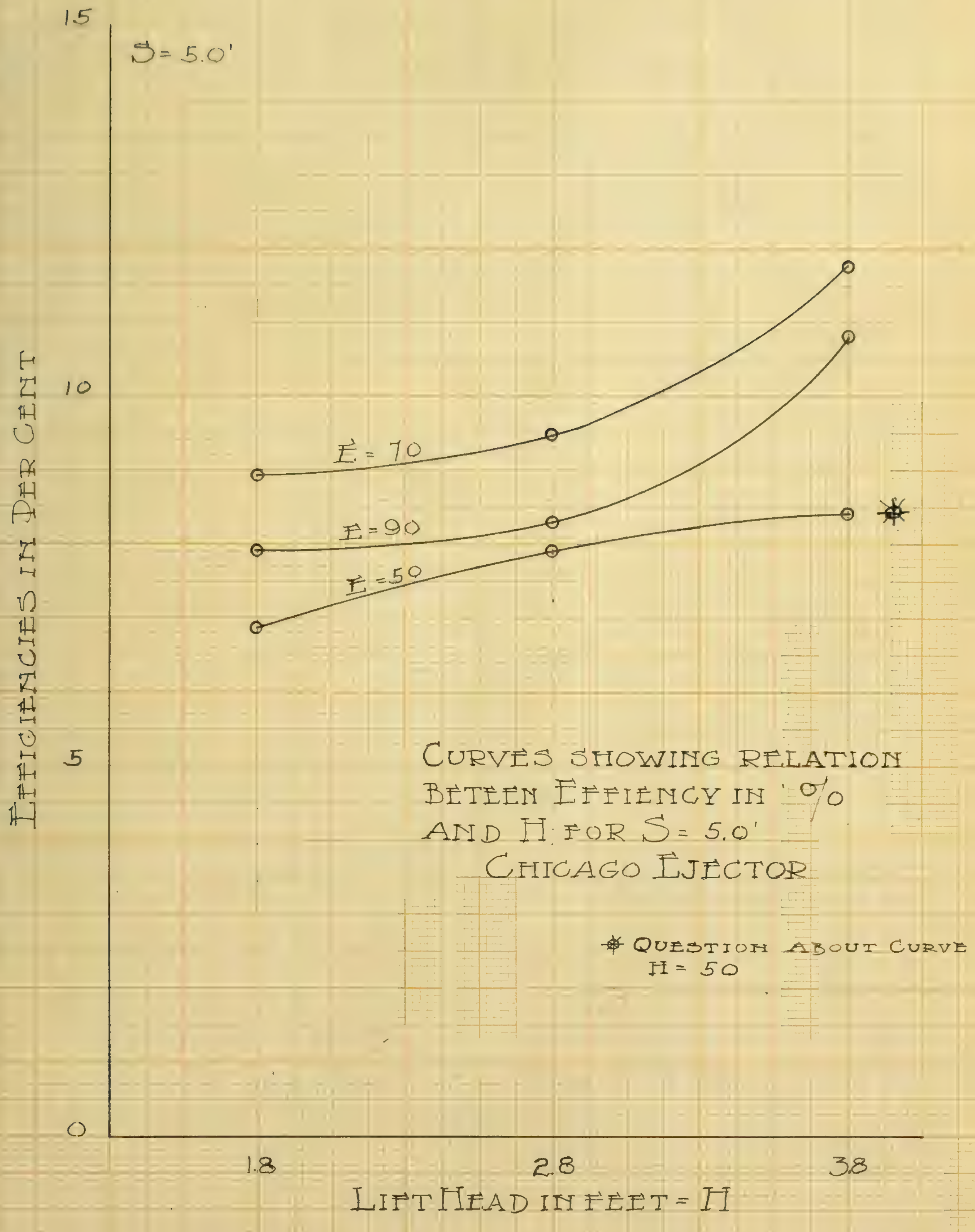
# Curve Sheet 1



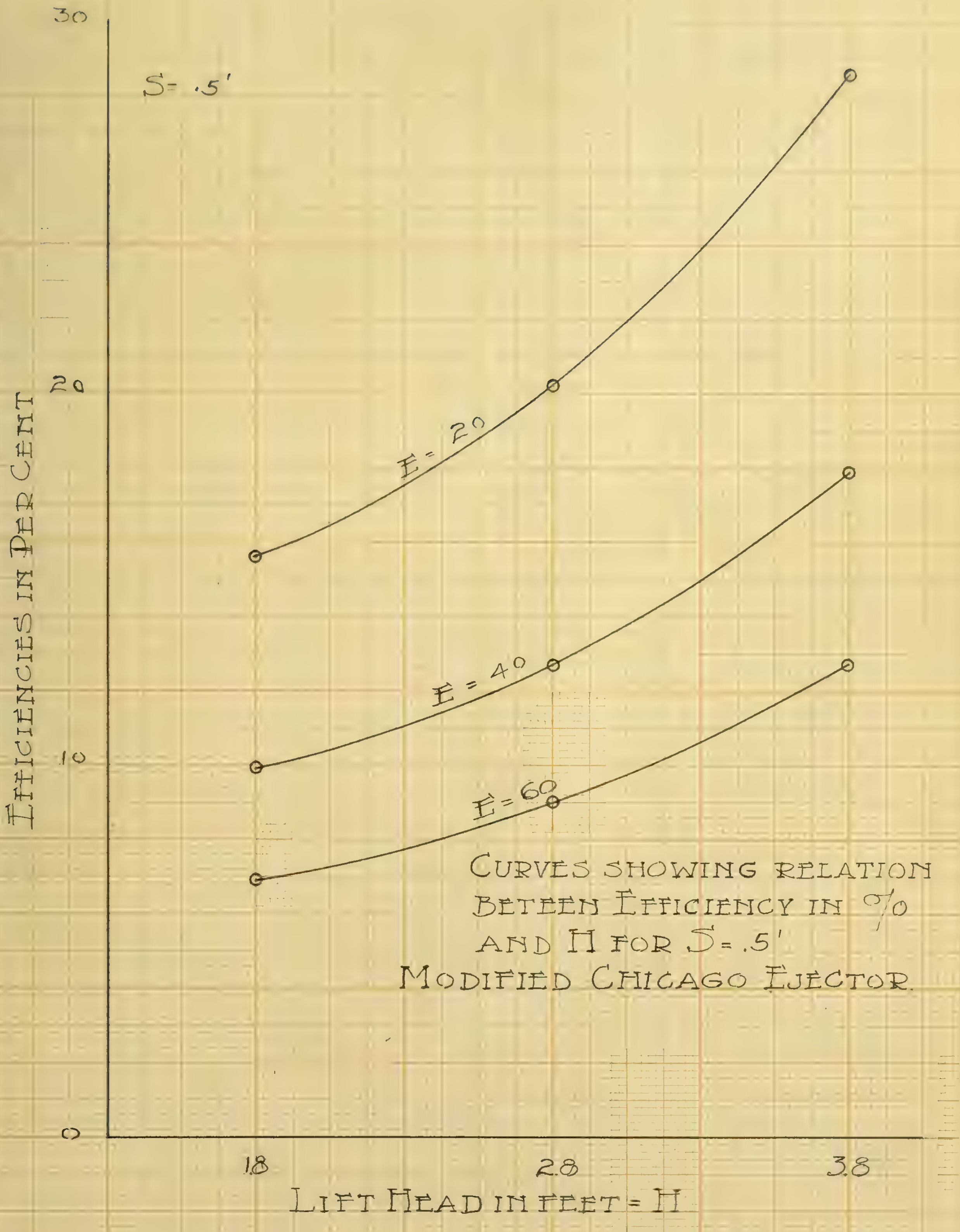
# Curve Sheet 2.



CURVE SHEET 3

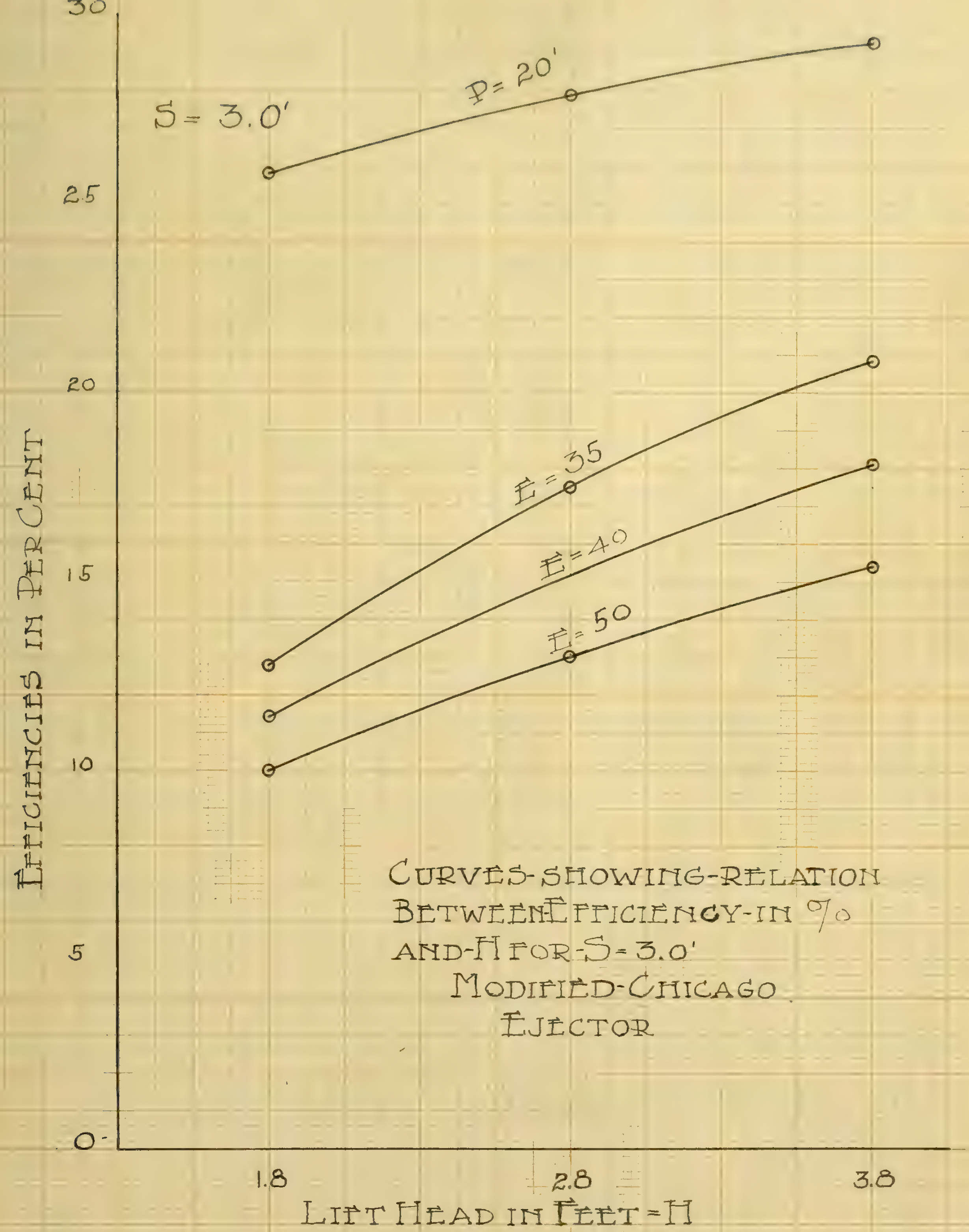


CURVE SHEET 4




CURVES SHOWING RELATION BETEEN EFFICIENCY IN % AND H FOR S = .5'
MODIFIED CHICAGO EJECTOR.

# Curve Sheet 5.



## Conclusions

A few preliminary experiments the results of which are shown in table C were made with the jet pump which was built up of pipe fittings. These experiments were made more to find out whether this style of pump would work than to make a thorough investigation of its efficiencies. The results show that the efficiencies are lower than those obtained with the Chicago Ejector. This is due, at least partially to the fact that in the ejector used some little trouble was experienced in keeping the jet from impinging against the inside walls of the discharge tube, thereby causing impact losses. There was also some difficulty found in keeping the joints air-tight. Although the results of table C do not compare favorably with those of tables A and B, yet they do show that an ejector built up in this way will

give fairly good results.

The results of the experiments performed with the two forms of the Chicago Ejector are shown in tables A and B. The columns under the head of 'Efficiency' show the ratio of the work done to the energy expended. The column headed 'Gallons pumped per gallon used' shows the quantity of water pumped per gallon used. The best method of explaining the tables is to study the curve sheets 1 to 5.

The ordinates of these curves represent the efficiency in per cent. The abscissas represent the lift heads in feet and for these two variables the pressure head E and the suction head S remain constant for each curve. Curve sheets 1, 2 and 3 are obtained from the experiments found in table A. We find in studying these curves that the efficiencies do not in any case range higher

than 12%. The highest efficiency obtained not plotted in Curve Sheets was 14.4 shown in experiment 29. This result was obtained by using a low suction head with a high lift head. The curves shown on sheet 3 for pressure heads of 70 and 90 feet curve in the opposite direction from the one shown for 50 feet and also from these shown on sheets 1 and 2. The facts shown most plainly from the curves on these sheets are:

(1) The efficiency is affected to a considerable extent by the lift head. The greater the value of H, the higher the efficiency.

(2.) The efficiency is affected by the pressure head $\overline{H}$ and also by the suction head S. The best combination of these two quantities for high efficiency is to use a low suction head with a low pressure head or a high suction head with a high pressure head.

Curve sheets 4 and 5, which were plotted from table B show that the efficiencies obtained by using the modified ejector, range quite a little higher than those obtained by using the original ejector. The facts given above can be applied here with the exception that although the efficiency is affected by the suction head and pressure head, yet the low pressure head gives the best efficiency with a low and also a medium high suction head. Tables D and E show the number of gallons pumped per gallon used for different values of E, H and S. These tables could not be filled out completely as there were not enough experiments made to do so.

In general, the number of gallons pumped per gallon used is decreased:

(1) As the lift head increases

(2.) As the suction head increases

(3.) As the pressure head decreases.

In general we find that this quantity decreases as the efficiency increases.

The advantages of this style of pump are:

(1) It has no values or parts that wear out easily

(2) It can pump muddy water.

(3.) It is very suitable for sewer work where high efficuncy is not required.

(4.) It is simple, light and easy to operate, easy to set up and easy to move.

The main disadvantage is that it is not an efficient pump.